<International Research Center for Elements Science> Photonic Elements Science

International Research Center for Elements Science - Photonic Elements Science -

http://www.scl.kyoto-u.ac.jp/~opt-nano/index-e.html

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Scope of Research

Our research interest is to understand optical and quantum properties of nanometer-structured materials and to establish opto-nanoscience for creation of innovative functional materials. Optical properties of semiconductor quantum nanostructures and strongly-correlated electron systems in low-dimensional materials are studied by means of space- and time-resolved laser spectroscopy. The main subjects are as follows: (1) Investigation of optical properties of single nanostructures through the development of high-resolution optical microscope, (2) Development of nanoparticle assemblies with new optical functionalities, and (3) Ultrafast optical spectroscopy of excited states of semiconductor nanostructures.

Research Activities (Year 2009)

Publications

Yamada Y, Yasuda H, Tayagaki T, Kanemitsu Y: Temperature Dependence of Photoluminescence Spectra of Nondoped and Electron-doped $SrTiO_3$: Crossover from Auger Recombination to Single-carrier Trapping, *Phys. Rev. Lett.*, **102**, [247401-1]-[247401-4] (2009).

Matsunaga R, Miyauchi Y, Matsuda K, Kanemitsu Y: Symmetry-induced Nonequilibrium Distributions of Bright and Dark Exciton States in Single Carbon Nanotubes, *Phys. Rev. B*, **80**, [115436-1]-[115436-6] (2009).

Miyauchi Y, Hirori H, Matsuda K, Kanemitsu Y: Radiative Lifetimes and Coherence Lengths of One-dimensional Excitons in Single-walled Carbon Nanotubes, *Phys. Rev. B*, **80**, [081410(R)-1]-[081410(R)-4] (2009).

Tayagaki T, Fukatsu S, Kanemitsu Y: Photoluminescence Dynamics and Reduced Auger Recombination in $Si_{1-x}Ge_x$/Si Superlattices under High-density Photoexcitation, *Phys. Rev. B*, **77**, [041301(R)-1]-[041301(R)-4] (2009).

Presentations

Exciton Radiative Lifetimes and Their Temperature Dependence in Single-Walled Carbon Nanotubes, Miyauchi Y, Matsunaga R, Hirori H, Matsuda KT, Kanemitsu Y, 2009 APS March Meeting, 16–20 March 2009, Pittsburgh, USA.

Luminescence and Magnetic Properties of Co Doped ZnO Nanocrystals, Taguchi S, Tayagaki T, Kanemitsu Y, European Materials Research Society (E-MRS), 8–12 June 2008, Strasbourg, France.

Exciton Fine Structures and Dynamics Studied by Single Carbon Nanotube Spectroscopy, Matsuda K, 3rd Workshop on Nanotube Optics & Nanospectroscopy (WONTON'09), 7–10 June 2009, Sendai, Japan.

Quantized Auger Recombination and Carrier Multiplication in Semiconductor Nanoparticles and Carbon Nanotubes, Kanemitsu Y, Ueda A, Tayagaki T, Matsuda K, 23rd International Conference on Amorphous and Nanocrystalline Semiconductors (ICANS 23), 23–28 August 2009, Utrecht, Netherlands.

Grants

Kanemitsu Y, Microscopic Spectroscopy of Highly Excited State in Semiconductor Nanostructures and Exploring Novel Optical Functionality, Grant-in-Aid for Scientific Research on Innovative Areas, 13 November 2008–31 March 2013.

Matsuda K, Optical Quantum State Manipulation of Carbon Nanotubes, Grant-in-Aid for Scientific Research (B), 1 April 2008–31 March 2011.

Temperature Dependence of Photoluminescence Spectra of Nondoped and Electron-doped $SrTiO_3$: Crossover from Auger Recombination to Single-carrier Trapping

Transition metal oxides have attracted a great deal of attention as new device materials due to their wide variety of fascinating and multifunctional properties. $SrTiO_3$ is one of the most important oxide materials. We studied photoluminescence (PL) decay dynamics in highly photo-excited $SrTiO_3$ crystals at low temperatures. The PL spectrum and dynamics show abrupt changes below 150 K in both nondoped and electron-doped $SrTiO_3$ samples. We clarified that the PL dynamics in both nondoped and electron-doped $SrTiO_3$ is well described by the same simple model involving single-carrier trapping, radiative bimolecular recombination, and nonradiative Auger recombination. The unusual temperature dependence of PL dynamics is caused by the crossover from Auger recombination at high temperatures to single-carrier trapping at low temperatures.

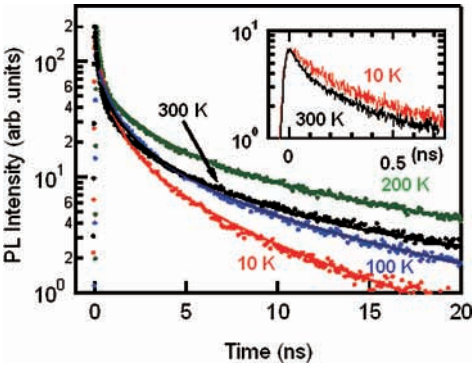

Figure 1. Temperature dependence of PL decay curves of nondoped $SrTiO_3$. Inset: PL decay profiles in the sub-nanosecond region.

Mn-Mn Couplings in Mn-doped CdS Nanocrystals Studied by Magnetic Circular Dichroism Spectroscopy

Fabrication and characterization of semiconductor nanocrystals (NCs) doped with functional impurities have been extensively studied due to interest both in the fundamental physics and potential applications in optoelectronic devices. We studied on the optical and magnetic properties of Mn-doped CdS nanocrystals coated with a ZnS shell layer (CdS:Mn/ZnS core-shell nanocrystals) by magnetic circular dichroism (MCD) spectroscopy. The magnetic field and temperature dependences of the MCD spectrum show paramagnetic behavior of the CdS:Mn/ZnS core-shell nanocrystals. The MCD intensity increases with the Mn concentration up to a few mol-%, and then starts to decrease rapidly. This Mn-concentration dependence of the MCD intensity can be explained by the formation of Mn-Mn pairs in heavily doped nanocrystals.

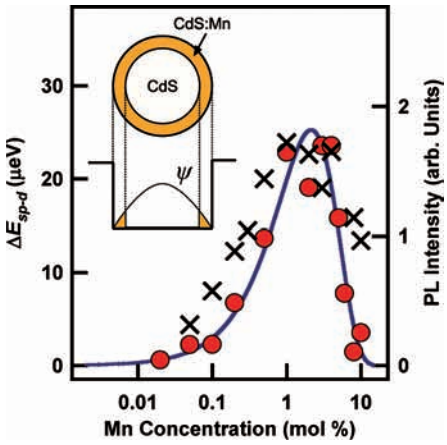

Figure 2. The splitting energy due to *sp-d* exchange (circles) and PL intensities (crosses) of Mn-doped CdS NCs as a function of the Mn concentration. Inset: Schematic illustration of model Mn-doped CdS NC.

Photoluminescence Dynamics and Reduced Auger Recombination in $Si_{1-x}Ge_x/Si$ Superlattices under High-density Photoexcitation

Electronic and optical properties in various types of Si nanostructure have been extensively studied both from the viewpoint of fundamental physics and the potential application to electronic and optical devices. We studied PL dynamics and multi-exciton recombination in $Si_{1-x}Ge_x/Si$ superlattices under high-density excitation. Saturation of the PL intensity and rapid PL decay are observed as the excitation laser intensity is increased. These phenomena occur due to nonradiative Auger recombination of the electron-hole pairs. The Auger process in $Si_{1-x}Ge_x/Si$ superlattices is less pronounced than that in the $Si_{1-x}Ge_x/Si$ single quantum wells. Our findings show that coupled nanostructures have an advantage in efficient light emission and the control of many-body carrier dynamics.